2. Measurement principle

Radiant heat flux is essentially a radiometric quantity representing the broadband irradiance or flux received per unit area by a surface. For a radiometer placed in front of a radiant source, the governing measurement equation for the radiometer signal output (V) is

$$V = G \cdot \iint dxdy \iint \cos\theta d\theta d\phi \int d\lambda \; L(x, y, \theta, \phi, \lambda) \cdot R(x, y, \theta, \phi, \lambda) \;, \tag{1}$$

where x and y specify the location on the radiometer on which radiant flux is incident, θ and ϕ specify the direction from which radiant flux is incident on the radiometer, λ is the wavelength, L is the radiance of the incident radiant flux, R is the responsivity of the radiometer, and G is the amplifier gain. The integrals are performed over the entire area of the radiometer upon which radiant flux is incident, over all directions from which radiant flux is emitted by the source and received by the radiometer, and over all wavelengths to which the radiometer is sensitive. Any temporal dependence is excluded in Eq. (1) since heat flux measurements are typically performed under steady-state conditions.

For a given range of directions for the source and radiometer, integration of Eq. (1) over the angles yields

$$V = G \cdot \iint dxdy \int d\lambda \; E(x, y, \lambda) \cdot R(x, y, \lambda) \;, \tag{2}$$

where E is the irradiance. Note that the integral over angles to obtain Eq. (2) depends on both the size of the source and the field-of-view of the radiometer. Also, the incident radiant flux at the reference plane of the radiometer is measured, not the absorbed flux. Effects from a window or the absorptance of the detector are included in the responsivity.

Integrating Eq. (2) over the area of the radiometer, assuming the responsivity is uniform over the area, yields

$$V = G \cdot A \cdot \int d\lambda \; \overline{E}(\lambda) \cdot R(\lambda) \;, \tag{3}$$

where A is the area of the radiometer over which radiant flux is incident and $\overline{E}$ is the average irradiance. The average irradiance is used in Eq. (3) because in nearly all measurement situations the irradiance has a spatial distribution that is a maximum at the center of the radiometer. Therefore, the average irradiance will depend upon the size of the radiometer.

Finally, a typical radiometer used as a heat-flux sensor has a responsivity that is independent of wavelength, so Eq. (4) reduces to

$$V = G \cdot A \cdot \overline{R} \int d\lambda \; \overline{E}(\lambda) \;, \tag{4}$$

where $\overline{R}$ is the average responsivity over wavelength. The product of the amplifier gain, area, and the average responsivity is the quantity calibrated for heat-flux sensors.